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Spontaneous formation and characterization of silicon carbide nanowires produced via thermolysis

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We report on experiments to optimize the process of preparation of silicon carbide nanowires (SiCNWs) by a combustion synthesis (thermolysis). The morphology of starting reactants and combustion atmosphere were varied and we observed the effect of those variables on product yield and characteristics. The produced SiCNWs were characterized using SEM, TEM, XRD, and wet chemistry analysis.

High-pressure reactor used for combustion synthesis, combustion reaction, and TEM of produced SiCNW

1 Introduction One-dimensional (1D) nanomaterials show novel and excellent properties [1], especially interesting for electronics and materials science. Superior to the properties of "bulk materials," the unique chemical, thermal, mechanical, and electronic [2] properties of 1D SiC nanostructures can be useful in many fields of science and technology. Because of its size (diameters of tens of nm and aspect ratio well above 10^3), this material possesses excellent field emission, semiconducting [3] and photocatalyst properties [4], tunable photoluminescence [5], and can also modify the characteristics of composites [6]. The production techniques of 1D nanoSiC are, however, time- and energy-consuming [7]. We present here a relatively simple, fast, and efficient growth of silicon carbide nanowires (SiCNWs) using a combustion synthesis technique (SHS) [8] following the reaction:

$$2n\mathrm{Si} + (\mathrm{CF_2CF_2})_n \rightarrow n\mathrm{SiC} + n\mathrm{C} + n\mathrm{SiF_4}.$$

This process makes use of a thermal-explosion and autogenous mode of extremely fast redox reaction between the strong reducing agent (Si) and oxidant (PTFE).

2 Experimental Thermolysis synthesis was carried out in a high-pressure reactor following the procedure outlined elsewhere [9]. The starting mixtures were prepared from fine powders of elemental Si and PTFE (particle size 1 μm, Aldrich) tumbled in a mechanic shaker for 15 min (PTFE). Two types of Si material (Fig. 1) were used: (i) microSi – particle size below 43 μm (99% Aldrich) and nanoSi – particle size below 100 nm (98% Alfa Aesar).

The stoichiometric mixture of reactants (ca. 5 g) was placed in a quartz crucible inside the reactor. The chamber was filled with various gases (air, N_2, Ar, and O_2) at the initial pressure equal to 1 MPa. The thermolysis was initiated by resistive heating of a carbon tape immersed inside the reactants in the crucible. It took usually only 1–2 s [10] to accomplish the process, accompanied by an abrupt increase in pressure and temperature. After the combustion was completed, the gaseous products were vented. The solid products (Fig. 2) have different morphologies depending on